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PRACTICAL INFORMATION FOR BEGINNERS IN IRRIGATION.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., July 3, 1906.

Sir: I have the honor to transmit herewith the manuscript for a Farmers' Bulletin, giving practical information for beginners in irrigation, prepared by S. Fortier, engineer in charge of Irrigation Investigations of this Office in the Pacific district. There is a great wave of emigration to the West and activity in canal construction, throwing open to settlement large areas of land which must be irrigated. The greater number of the settlers for these lands will come from regions where irrigation is not practiced, and the whole system of agriculture which they must practice will be new to them. In this paper Professor Fortier has attempted to bring together the information which will be most needed by these beginners in irrigation. Its publication as a Farmers' Bulletin is recommended.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary.

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PRACTICAL INFORMATION FOR BEGINNERS IN IRRIGATION.

INTRODUCTION.

There are several million acres open for settlement in the United States under irrigation works built by private enterprise, and works are being constructed by the National Government to provide a water supply for more than a million acres of arid lands. So large an area of fertile land provided with a water supply and the widespread interest manifested in irrigation are certain to cause an influx of settlers into western America during the next few years. These settlers are likely to come from humid regions, where many of the methods used in irrigated farming are neither practiced nor understood, and unless an opportunity is given this class to become familiar with proper methods their efforts may result in failure. The purpose of this bulletin is to give such information as will best serve the interests of these new settlers. The chief difficulty encountered in its preparation was to make it both accurate and applicable to a large number of localities. On account of the limited space, the extent of territory included, and the wide diversity in the soils, crops, and climate of the arid regions, it was found impossible to give as much detailed description as would otherwise seem desirable.

The first few pages of the bulletin contain some suggestions to those who are confronted with the task of selecting a farm under an irrigation system. Arid soils and water supplies are considered in a general way from the standpoint of the irrigator. The greater part of the paper is taken up with a somewhat fuller description of how to locate and build farm ditches, how to prepare land to receive water, how to irrigate a few of the staple crops, and how much water to apply.

SELECTION AND LOCATION OF AN IRRIGATED FARM.

Climate and crops.—The intending settler, in deciding where to locate, will be guided to some extent by the climate and the crops which can be profitably grown. Those who prefer a mild winter climate will be naturally attracted to the southern belt of the arid States, which includes

Texas, New Mexico, Arizona, and the greater part of California. Those who prefer cooler summers, coupled with short winters of frost and snow, will find a location suited to their tastes in the central belt, extending from western Kansas through Colorado, Utah, Nevada, and north on the Pacific slope to eastern Oregon and Washington. Those who come from northern latitudes will do well to consider Nebraska, the Dakotas, Wyoming, Idaho, and Montana. The soil and climatic conditions will determine to a large extent the crops to be grown.

Character and depth of soil.—In choosing land which is to be irrigated a careful examination should be made of the character and depth of the soil, its behavior when irrigated, the slope and evenness of the surface, the presence of injurious salts, and the facilities for drainage. One of the best indications of the character of the soil is the native vegetation which grows on it. When sagebrush, buffalo grass, or cactus is found on a tract, it is reasonably certain that the soil is fertile, easily tilled, and well drained. The plants named are but a few out of a large group which grow on good soil, easily irrigated. On the other hand, the presence of greasewood, saltwort, salt weeds, or other similar plants is indicative of a heavier soil, less easily cultivated, and containing more or less of the injurious salts usually grouped under the common name of alkali.

In arid regions cultivated plants are deep rooted. They draw their supply of plant food and moisture from considerable depths, and the deeper the soil the larger is the feeding ground for the roots and the greater is the capacity to store water. In the warmer parts of the West the top layer of soil is used chiefly as a sort of blanket to protect the moist soil beneath, which furnishes both food and water to the fibrous roots. The presence of any hard, impervious stratum lying between the first and fifth foot prevents deep rooting and the storage of moisture. A hard stratum lying between the fifth and tenth foot is likewise injurious, but to a less extent. On the other hand, a porous stratum of coarse gravel may waste large quantities of irrigation water by permitting it to percolate beyond the root zone. It, however, insures good drainage, and is more desirable than an impervious subsoil. The character of the subsoil may be readily determined by boring holes with a suitable soil auger to a depth of 10 feet, if necessary, and taking samples of soil at different depths.

Absorption of water by the soil.—Easily irrigated soil will absorb sufficient water in twenty-four hours after an irrigation to become moist to a depth of 2 or 3 feet. Some soils are so impervious that it is difficult to wet more than a few inches below the surface and others are so porous that the water soon percolates through them beyond the reach of the deepest roots. The surface of other soils bakes and cracks after each wetting, which renders cultivation difficult. It will usually be possible to find similar soils under irrigation in near-by

fields, but if this is not possible, a trial may be made on a small scale to determine how the soil acts under irrigation. In general, sandy loams irrigate well, while clay is hard to cultivate when wet, does not absorb water readily, and bakes and cracks when drying.

Surface conditions.—The intending purchaser should likewise examine with much care the nature of the ground surface. The best conditions are a smooth surface, with a uniform slope of 10 to 20 feet to the mile. Such land costs little to put in shape for the spreading of water over it, and the slope insures good drainage. At the other extreme, one finds land full of buffalo or hog wallows. These alternating heights and hollows are difficult to reduce to an even grade. Again, the land may be cut up by ravines, thereby increasing the labor and cost of putting water upon it, or it may have too much or too little slope. If land which is naturally smooth on the surface and of the right slope costs $5 per acre to put in shape for irrigating, hog-wallow land may cost $15. Thus it is evident that the cost of preparing the surface is an important consideration in the first cost of the land. Besides, some hog-wallow land is inferior in quality, being frequently charged with injurious salts.

Drainage.—Good drainage is essential for a permanently productive irrigated farm. It is practically impossible to supply crops with sufficient water for the best growth without applying so much that some will seep into the subsoil. Unless this can flow away it will raise the level of the ground water until it comes near the surface, where it will cause an accumulation of alkali and will drown out crops. If land has not good natural drainage it must be supplied artificially, but this need not be done until a few crops have been raised.

THE WATER SUPPLY.

Value of a water right.—The market value of a water right for irrigation purposes is usually about one-third the value of the land. The actual value when measured by the increased yield which it produces is much greater. The reason why water rights sell below their value to the farmers is largely due to uncertainty regarding titles. In very many cases water rights have never been defined or established, and a careful examination is necessary before purchasing such rights.

How irrigation water is obtained.—The water supply for a farm in any one of the Western States and Territories may be obtained from the unappropriated waters of a natural stream, from a canal company which has water to sell, or from one of the Government irrigation projects, but usually a single tract can secure water from only one source. Under favorable conditions a single farmer may secure a water supply from a natural source, but more frequently it requires the united effort of a number of farmers. One of the best organizations for united

effort of this kind is a cooperative or mutual water company, in which the owners of the land to be irrigated become the owners of the stock in the water company. Before diverting water from a stream the individual or manager of a company should first seek advice from the proper State officials. In most of the western commonwealths the appropriation, diversion, and distribution of the public waters have been placed under the supervision and control of a State engineer or a State board of irrigation, with quarters at the State capital. Information may be obtained from these officials regarding the regulations governing the appropriation and diversion of water, the flow in any particular stream, the volumes which have been appropriated and used, and the balance, if any, which is subject to appropriation. Information may also be obtained from subordinate officials who have immediate charge of distributing water. In States and Territories which have no officers to regulate and control the distribution of water, the intending settler would do well to get the opinion of some reliable lawyer who is familiar with existing rights to the use of water in the neighborhood. Some local engineer may also be profitably consulted with reference to the amount and reliability of the water supply from a particular source.

Reservoirs and pumping.—In the older districts, where the stream flow in summer has been appropriated, a supply can often be obtained by building a storage reservoir or by installing a pumping plant. Small enterprises of this character may be undertaken by individuals, associations, or mutual companies. A large number of small and medium-size reservoirs have been built by the farmers living in the basins of the Cache la Poudre and Big Thompson rivers, in northern Colorado. These have been described in the Yearbook of the Department of Agriculture for 1901 and in Bulletins 92 and 134 of the Office of Experiment Stations, and the reader is referred to these publications for information on this subject. In southern California, in Santa Clara Valley and in portions of the San Joaquin Valley, the greater part of the water supply is obtained by pumping water from wells. Results of investigations made on pumping plants in these localities are contained in Bulletin 158 of the Office of Experiment Stations, to which the reader is referred for information on the kind of pumping plants used and their cost and efficiency.

Large canals.—The most common source of water supply for the new settlers in irrigated districts is likely to be an irrigation canal built by private enterprise or by the Government for the purpose of supplying water to farmers. Before completing arrangements to take water from a private company one should make a careful examination of its ability to furnish an adequate supply at such times as will best meet the needs of the crops to be grown. A few of the most impor-

tant features of canal water rights are outlined in the following paragraphs:[a]

(1) When two or more canal companies take water from the same stream, which is subject to wide fluctuations in flow, those whose rights were acquired last are the first to suffer when scarcity exists. Between the ditch owners who were the first to divert water and those which were last there is a wide range of conditions which vitally affect the value of the water rights under each. Some canals have an abundance of water throughout the crop-growing season; others carry a full volume during the flood season and a diminished volume during the remainder of the time. Some fail to provide an adequate supply for the last irrigation of such crops as alfalfa and potatoes, while others are likely to have their entire supply shut off after the spring floods have subsided. It is thus apparent that there are all sorts of canal rights to the use of water, and the value of a water user's right to a portion of the volume carried by a canal will depend, to a large extent, on the nature of the stream from which the supply is taken, the priority of the canal, the number of water rights sold, the amount allowed for each irrigation or for the season, and the general efficiency of the system.

(2) Companies dispose of the water conveyed in canals by making contracts with individual owners. The contracts usually provide for the sale of a perpetual water right for a given tract of land, with an additional annual charge for the operation and maintenance of the canal system. Under some canals the purchase of a water right is not required, the total charge for water being paid annually in the way of water rental. In all mutual or cooperative companies the water users are the shareholders, and some canals which are at first operated and controlled by capitalists or nonresidents become mutual companies by selling to each water user an interest in the company and the property owned by it.

(3) Contracts vary much as to the quantity of water which the company agrees to furnish. Probably the most common is a stream of a given size, say 1 cubic foot per second for each 80 acres of land, on condition that the purchaser will turn off the water when it is not needed. Others agree to furnish enough to cover the land to a given depth, say 2 feet, during each season. Practically all such contracts provide, however, that in case of shortage of water the company shall "prorate" what water it has. That is, in case the company has not enough water to supply all it has contracted to deliver, it shall divide what it has among all its contract holders. Few canals have all the time enough water to fill all contracts, and the effect of such a contract is that the purchaser is to receive a share of what water the

[a] For a fuller discussion of canal water rights, see Office of Experiment Stations Buls. 58, 140, and 157; Irrigation Institutions, by Elwood Mead (New York, 1903).

company gets rather than a stream of a given size or a fixed quantity during the season, the share received depending on the number of water rights sold. The effect in mutual companies is the same. The settler buys, instead of a water right, a share in the company, and each share entitles its holder to a portion of whatever water the canal carries. The same is true in irrigation districts. In fact, under practically every form of water right not directly from a stream, the farmer gets a share of the available supply rather than a fixed quantity. Under most contracts a short supply does not decrease the charge to the customer. This shows the necessity for paying as much attention to the rights of the company as to the form of the contract.

(4) The value of contract water rights likewise depends on the way the canal is managed. Care and efficiency in maintenance and operation, equitable distribution of water, and sufficient resources to meet all necessary expenses are important factors in determining the value of water rights.

(5) Attention should also be given to the permanency and stability of the canal system. Floods and fire frequently destroy canal structures, and before they can be repaired crops may suffer or perish for lack of water. So, also, breaks are liable to occur at the weak points and the repairing of these necessitates the turning off of the supply, which injuriously affects the owners of water rights.

Government works.—Water for irrigation purposes may also be obtained at the stipulated price per acre from one of the Government irrigation projects. Of these, several are nearing completion. When the Government undertakes to furnish water to lands in private ownership it does so through a water users' association in which all of the landowners within the project become shareholders in the association. The cost of a water right under a Government project varies from about \$15 to \$40 per acre. This sum is payable in ten equal annual installments, and a failure to make any two payments when due may forfeit the right. When the payments for the water for the major portion of the land under any project have been made, the operation and management of the irrigation system, exclusive of all storage reservoirs, passes to the owners of the lands irrigated, to be maintained and operated at their expense. The cost will then be a pro rata share of the actual operating expenses.

FARM DITCHES.

Whatever the source of supply, a network of ditches to convey the water to all parts of the farm is necessary. The larger ditches and canals need not be considered in this connection, for they are usually built by contractors under competent engineers; but the location and building of farm ditches is done in most instances by the farmers

without assistance from engineers or surveyors. The following features of farm ditches are briefly discussed for the benefit of the inexperienced:

CAPACITY.

The capacity needed depends chiefly on the manner of delivering the water and the method used in applying it. It also depends, but to a less extent, on the size of the farm, the duty of water, the nature of the soil, and the crops raised.

In Montana, Wyoming, and Idaho, as well as in parts of other States, water is usually delivered in continuous streams which for an average-size farm seldom exceed 80 miner's inches, or 2 cubic feet, per second. The supply ditches for the farms are accordingly small, except for the large holdings.

In Utah, New Mexico, Arizona, California, and to some extent in other States and Territories water is delivered to the user during short periods of time, with long intervals between when the supply is entirely shut off. The volume delivered depends on the way it is applied and the time of use.

In the citrus orchards of California the size of the streams delivered varies from 30 to 60 miner's inches.[a] At Riverside, where the soil is a clay loam, the usual allotment is 30 inches for forty-eight hours once a month or 30 inches for seventy-two hours every six weeks on a 10-acre tract. Around Pomona, where the soil is sandy, the usual head is from 50 to 60 inches, the larger head being for a shorter time.

On the diversified farms of Utah and Colorado the supply ditches vary in capacity from 50 to 150 miner's inches.

In irrigating alfalfa and meadows by the border and check methods of irrigation, as practiced in Arizona and California, and in the use of water during the rainy winter seasons of the Pacific coast, large volumes are used. Supply ditches are accordingly built to carry 300 to 500 miner's inches. The size must be determined with reference to the crops to be grown, their acreage, the method to be adopted in watering them, and the regulations governing the delivery of water to the ditch.

FORM.

The form depends largely on the implements used in making the excavation. Figures 1 and 2 represent the cross sections of two ditches

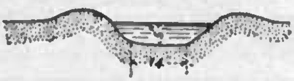

FIG. 1.—Farm ditch No. 1.

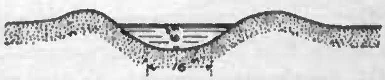

FIG. 2.—Farm ditch No. 2.

made by ditch plows attached to sulky frames. The ditches are afterwards cleaned out by hand. The first of these is made with a 14-inch

[a] In southern California 50 miner's inches are equal to 1 cubic foot per second.

lister and will carry from 25 to 70 miner's inches, depending on the grade, and the second is made with a 16-inch lister and will carry 30 to 95 miner's inches. The ditch shown in figure 3 is a somewhat

FIG. 3.—Farm ditch No. 3.

larger one and is intended to carry 80 to 270 miner's inches. It may be made by first plowing a strip where the ditch is to be and then removing the loose soil by a scraper or V-shaped crowder (fig. 4).

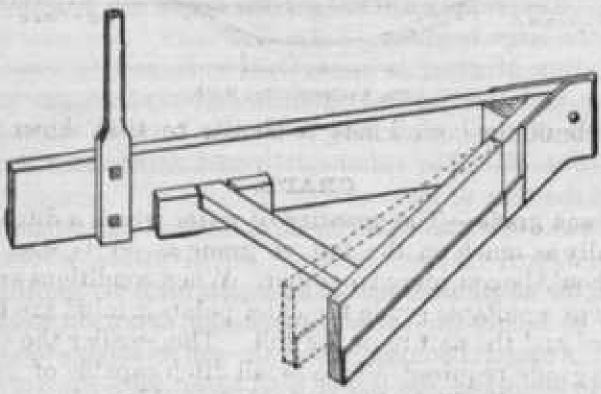

FIG. 4.—Adjustable "V" scraper or crowder.

Farm ditch No. 4, which has a capacity of 150 to 530 miner's inches, according as the grade is flat or steep, may be made trapezoidal, as shown in figure 5, or curved, as shown in figure 6. The first repre-

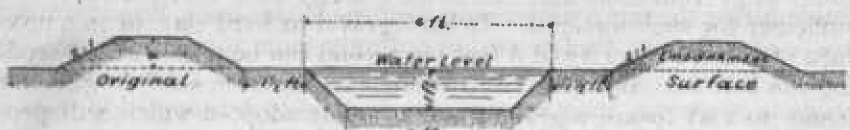

FIG. 5.—Farm ditch No. 4.

sents the shape of a ditch made by one of the many kinds of graders which remove the earth from the excavation and deposit it on the embankments at some little distance from the edge. The second rep-

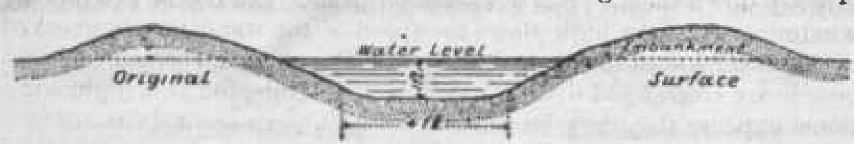

FIG. 6.—Farm ditch No. 4.

resents the shape of a ditch made with a plow and scraper, or else by a plow and one of the many kinds of homemade devices used for removing loose dirt from ditches.

Two forms may likewise be given to the ditch shown in figures 7 and 8, which has a capacity of 450 to 1,250 miner's inches,

FIG. 7.—Farm ditch No. 5.

depending on the grade. A ditch of this size is often built by an association of farmers to convey water to a number of ranches. The

FIG. 8.—Farm ditch No. 5.

manner of building both kinds is similar to that shown in figures 5 and 6.

GRADE.

Capacity and grade.—The quantity of water which a ditch will carry depends fully as much on the fall or grade as on its size. The two elements should be considered together. When conditions are such that one can adopt a suitable grade the chief points in mind are the volume to be carried and the nature of the soil. The smaller the volume the greater the grade required. In a small ditch capable of carrying 50 miner's inches a fall of 2 inches to the rod would produce a velocity of 2 feet per second, while in a ditch capable of carrying 950 miner's inches the fall required to give the same velocity is only one-fourth inch to the rod. In fine sand or sediment a flat grade is required in order to prevent scouring. A mean velocity of 1 foot per second is sufficient for such material. In hard gravel or hard clay, or in a mixture of these, a velocity of 3 feet per second can be used without eroding the bottom. In ordinary materials, ranging from sandy or gravelly loams to clay loams, a grade may be safely adopted which will produce a mean velocity of 2 to 2½ feet per second. On a farm with little fall the grade of a ditch can not exceed that of the land. On rolling land or where the slope is steep a suitable grade for ditches can usually be found by running them across the slopes rather than directly down them. When excessive grades can not be avoided by winding around the high places the speed of the water may be checked by the insertion of drops or flashboards at proper intervals. Checkboards are convenient to divert water into laterals, and at a slight additional expense they may be combined with a permanent drop.

Flow of water in farm ditches.—In the table which follows, the flow in each of the five types of farm ditches previously shown (figs. 1 to 8) has been figured for different grades. These grades are intended to cover ordinary conditions on most farms and are expressed in three

ways: First, in inches and fractions of an inch per rod; next in feet per 100 feet; and, lastly, in feet per mile. The mean or average velocity of the water in each kind of ditch having a given grade is also given, as well as the discharge in cubic feet per second and its equivalent in miner's inches under a 6-inch pressure head, about 40 of such inches being equal to 1 cubic foot per second. Thus in farm ditch No. 3 a grade of one-half inch per rod produces a discharge of 168 miner's inches, but when the grade is increased to three-fourths inch per rod the discharge is 207 miner's inches:

Table giving the mean velocity and discharge of ditches with different grades.

Grade.			Mean velocity in feet per second.	Discharge.	
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.	Miner's inches under 6-inch pressure head.
FARM DITCH NO. 1.—FIGURE 1.					
1-2	0.25	13.33	1.01	0.67	27
3-4	.38	20.00	1.23	.81	32
1	.51	26.67	1.42	.93	37
1 1-4	.63	33.33	1.59	1.05	42
1 1-2	.76	40.00	1.75	1.16	46
2	1.01	53.33	2.04	1.35	54
2 1-2	1.26	66.67	2.28	1.50	60
3	1.51	80.00	2.50	1.64	66
3 1-2	1.77	93.33	2.70	1.78	71
FARM DITCH NO. 2.—FIGURE 2.					
1-4	0.13	6.67	0.82	0.80	30
1-2	.25	13.33	1.16	1.00	42
3-4	.38	20.00	1.42	1.30	52
1	.51	26.67	1.64	1.50	60
1 1-4	.63	33.33	1.84	1.70	67
1 1-2	.76	40.00	2.02	1.80	74
1 3-4	.88	46.67	2.18	2.00	80
2	1.01	53.33	2.34	2.10	86
2 1-2	1.26	66.67	2.61	2.40	96
FARM DITCH NO. 3.—FIGURE 3.					
1-8	0.06	3.33	0.79	2.08	83
1-4	.13	6.67	1.13	3.00	119
1-2	.25	13.33	1.60	4.20	168
3-4	.38	20.00	1.97	5.20	207
1	.51	26.67	2.28	6.00	239
1 1-4	.63	33.33	2.57	6.80	270
FARM DITCH NO. 4.—FIGURES 5 AND 6.					
1-16	0.03	1.58	0.84	4.20	168
1-8	.06	3.33	1.08	5.40	216
1-4	.13	6.67	1.54	7.70	308
3-8	.19	10.00	1.89	9.50	378
1-2	.25	13.33	2.20	11.00	440
5-8	.31	16.67	2.45	12.20	490
3-4	.38	20.00	2.69	13.40	538
FARM DITCH NO. 5.—FIGURES 7 AND 8.					
1-16	0.03	1.67	1.08	11.6	464
1-8	.06	3.33	1.48	16.7	666
3-16	.09	5.00	1.82	20.5	819
1-4	.13	6.67	2.11	23.7	950
5-16	.16	8.33	2.35	26.4	1,058
3-8	.19	10.00	2.58	28.0	1,121
7-16	.22	11.67	2.80	30.5	1,260

PLAN AND LOCATION.

Proper location of ditches.—Farm ditches should be located in the right place at the start. It is a mistake to build ditches for the lower part of a farm and then in after years, when there is a desire to irrigate the remainder, to be obliged to build a second series of ditches for the higher land. Sufficient water should first be conveyed from the canal or other source of supply to the highest point and from there distributed to the various subdivisions. In laying out these permanent ditches an effort should be made to locate them along field or fence boundaries, if possible, in order not to obstruct the passage of teams and implements in fields. When the grade is too steep to permit this a curved location through fields should be chosen. These curved locations for supply ditches can be so laid out as to add greatly to the beauty of an irrigated farm. They become the margins of fields, by the side of which lanes are graded, fences built, and shade trees planted. While the plan of locating supply ditches around the margins of square or rectangular tracts is perhaps more convenient for farm operations the curved lines produce a more pleasing effect.

Ditches on uneven land.—It often happens that a farm is more or less cut up by ravines or depressions which intersect or separate fields, and the supply ditches have to be extended across these low places. This is usually done in one of three ways. When the depression is not more than a few feet deep levees are built on each side; in other cases flumes are built on grade from side to side, and, lastly, the water may be carried across in a pipe laid in the form of an inverted siphon. The earth levee is the cheapest, but it is subject to leaks and washouts for the first few years. The wooden flume answers the purpose fairly well, but it is subject to early decay, and the clay or cement pipe laid beneath the surface, although dearer in first cost, is really the cheapest in the end.

Control of weeds.—The margins of supply ditches on most irrigated farms are the breeding ground of weeds. The seeds of these fall into the water and are widely scattered by the irrigation stream. The banks of ditches should be graded and smoothed so that the weeds which grow along the sides can be readily cut and burned. A rapid-growing forage crop like alfalfa also tends to keep down the weeds and may be sown along the banks for this purpose.

Instruments needed in laying out ditches.—In laying out supply ditches an engineer's level and rod are the most convenient instruments. The distances may be estimated by pacing. When such instruments are not available, a useful substitute consists of an ordinary carpenter's spirit level attached to a portable wooden frame, a sketch of which is shown in figure 9. When first made and placed on a level surface the bubble should come to the center of its run. Then one leg

is shortened by the amount of the grade per rod (see table of grades). The device is operated by one man, who first places the shorter leg at the surface of the water in the main canal or supply ditch and swings the other end around until the bubble comes to the center. The location of the longer leg is then marked by a helper, who carries a shovel

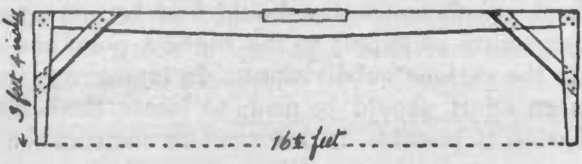

FIG. 9.—Homemade level.

and removes part of a shovelful of earth. The level is then carried forward until the shorter leg occupies the position vacated by its mate, when a second mark is made. This operation is repeated until the line is laid out and a furrow is run connecting all of the temporary marks.

STRUCTURES.

Head gates.—Each farmer needs a head gate to control the flow from the main or branch canal into his private ditch. This head gate should meet the requirements of both the canal company and the farmer. The interests of the company demand that it shall be water-tight when closed, large enough to admit the necessary flow, and so made that it can not be raised above a given height. The farmer is likewise interested in having a substantial head gate of ample size, but in addition he desires it to be designed in such a way that he can, when he chooses, close it partly or altogether. The head gate is placed at the edge of the canal and either a wooden box or pipe conveys the water under the embankment of the canal. When a wooden pipe is used a convenient type of head gate is that shown in figure 10. The box as shown is about 20 inches wide and 17 inches deep inside, and the gate which is made to fit this opening consists of two thicknesses of 1-inch boards. The upper part of the gate stem is a round steel rod threaded, and the lower part a piece of band steel welded to the rod. This flat portion is embedded between the boards of the gate and fastened with bolts. The gate is operated by means of a cast-iron handwheel, held in place by two cross timbers, which in turn are supported by posts resting on the box. The special nut, attached to a chain and locked, prevents the gate from being raised beyond a fixed point, yet it does not prevent the gate from being partially or wholly closed.

Measuring boxes.—Various devices are used to measure the water delivered to farmers, but one of the most common is the weir. Weir boxes are made small or large to suit the flow. The sketch given in figure 11 represents one of medium size, which will measure 35 to 200

miner's inches. It consists of a box or flume 12 feet long and over 5 feet wide. Eight feet from the upper end a weir board is inserted of the form and dimensions shown in the sketch. The water which enters the upper end of the box is first checked by the weir board and subsequently flows through the notch. The depth of water flowing through is measured by a gauge placed about 4 feet above the weir

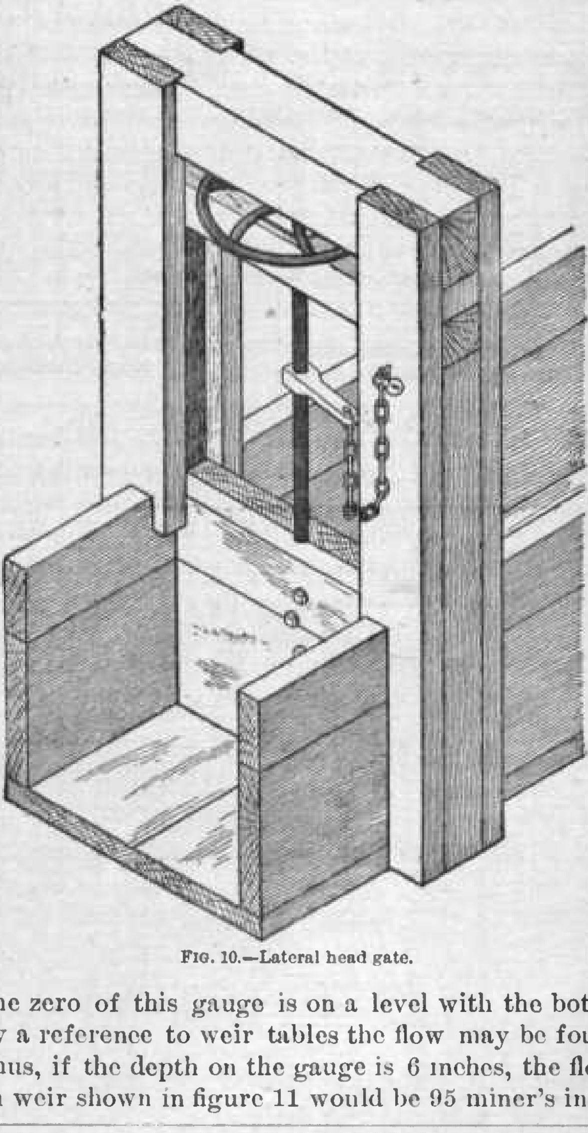

FIG. 10.—Lateral head gate.

board. The zero of this gauge is on a level with the bottom of the notch. By a reference to weir tables the flow may be found for any depth. Thus, if the depth on the gauge is 6 inches, the flow through the 24-inch weir shown in figure 11 would be 95 miner's inches.[a]

[a] For a more complete description of how to build and place farmers' weirs, and for weir tables adapted to farmers' use, the reader is referred to Montana Sta. Bul. 34.

Supply ditches for farms should likewise be provided with division boxes. These are inserted at the points where one or more laterals

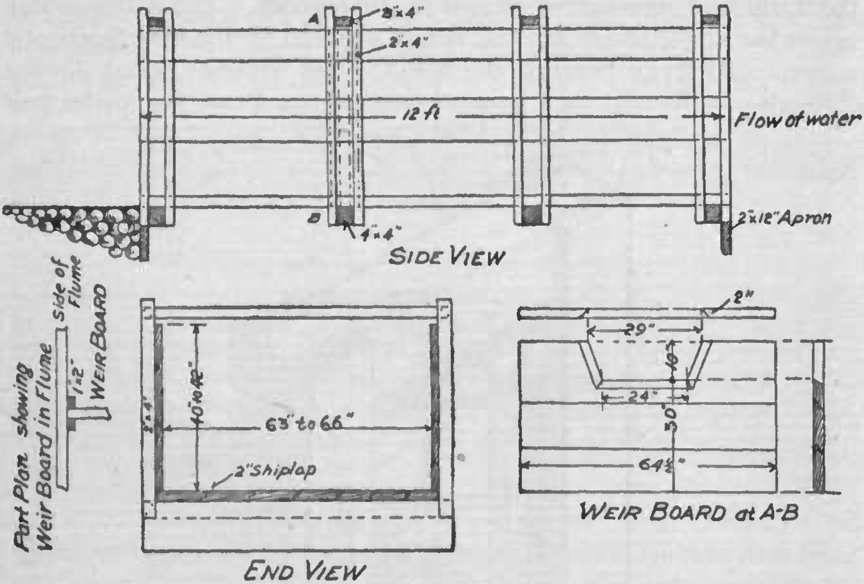

FIG. 11.—Plans of weir box.

branch out from the main supply ditch. In figure 12 the supply ditch extends up and down the page and a lateral branches out from each

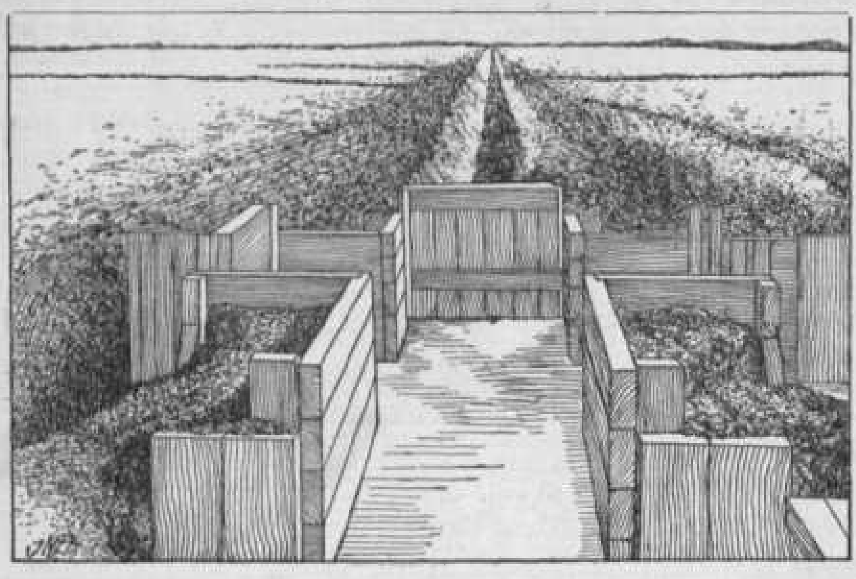

FIG. 12.—Division box in lateral.

side. The box is made of 2 by 4 inch joists lined with planks and the gates are formed of ship-lap flooring nailed to battens. By a proper

adjustment of the three gates all of the flow may be turned into any one of the three ditches or it may be divided in any way between these ditches.

PREPARATION OF LAND FOR IRRIGATION.

The preparation of land for irrigation should follow the building of supply ditches. While this rule is frequently disregarded it will be found better to grade land in conformity to permanent ditches already constructed than to locate and excavate ditches to suit land that has been graded and leveled.

Importance of surface preparation.—The new settler in an irrigated district seldom appreciates the importance of preparing the surface of fields so that they may be cheaply, easily, and properly watered. Crops in an arid climate are as a rule good or bad, according as they have received the proper amount of water at the right time, and when the ground is left so rough and uneven that water can not be evenly applied the effect is shown in the reduced yield. The preparation of the land is a first cost, and if done thoroughly during the first or second year little expense need be incurred afterwards. The difference in cost between a smooth, well-graded field and one which is poorly graded and rough may not exceed $5 per acre, yet this sum is often lost in one season by diminished yields due to imperfect watering, caused by a rough, uneven surface. Thorough preparation of the surface applies with particular force to a crop like alfalfa, which grows year after year from the roots, and which is cut from three to six times each season.

REMOVAL OF NATIVE VEGETATION.

Clearing the surface.—That portion of arid America which can be reclaimed by cultivation and irrigation is more or less covered with native vegetation of one sort or another. Tracts which produce native grasses, low cacti, rabbit brush, and the smaller forms of brush can be readily plowed without first removing the larger plants. Such land should be plowed deep, the larger growth afterwards removed and the surface thoroughly harrowed, graded, and smoothed. In plowing for the first time, 2 acres is a fair day's work for a man and three horses, and the cost of removing the larger plants seldom exceeds 50 cents an acre. Tracts which produce tall, coarse sagebrush from 3 to 5 feet high, in clumps from 4 to 8 feet apart, with more or less nutritious grasses growing in the open spaces, are more difficult to put in shape for irrigation. The methods used to remove native vegetation of this kind in the Yakima Valley, Washington, are described by Prof. O. L. Waller in the Report of Irrigation and Drainage Investigations for 1904,[a] and the following brief descriptions of methods employed and

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 158.

estimates of cost have been obtained chiefly from that source. The brush is first railed by dragging a 60-pound rail from 12 to 16 feet long across and back over the same strip in opposite directions by hitching a team of horses or mules to each end. Sometimes the rail is bolted to a heavy timber. Others use a chisel-sharpened plowshare steel bolted to a 12 by 12 inch timber and dispense with the rail. The loose brush is then gathered into windrows or piles by a brush rake and burned. These rakes are made either of wood with teeth of round oak or pine joists or of steel and resembling a strong and heavy self-dumping hayrake. The brush which is not torn out by the rail is grubbed out with a mattock.

Cost of clearing the surface.—The cost of removing and burning a heavy growth of brush in the manner just described is about $2.50 per acre. Brush which grows from 2 to 3 feet high in clumps about 8 feet apart can usually be removed and burned for $1.50 or less per acre. When sagebrush is grubbed out by hand the cost varies from $1.50 to $3 per acre, according as the growth is light or heavy. In localities where water is cheap and abundant sagebrush may be killed by being flooded, and when dry is readily raked into heaps and burned.

METHODS USED IN PREPARING LAND.

Many methods are used in western America, but the few herein described may be regarded as representative of all, the remainder being modifications of those named. A general knowledge of these is useful to the settler in that it enables him to compare their relative cost and efficiency, and assists him in deciding which is best suited to his conditions and to the size of his purse. Having made up his mind how to irrigate his farm, the construction of the supply ditches and the preparation of the surface should conform to this method from the start.[a]

SURFACE GRADING AND FIELD LATERALS.

Grading.—Land in the mountain States is first leveled, then graded and smoothed, and afterwards ditched. When water is applied to land prepared in this way it is termed "flooding from field laterals." A supply ditch is first dug to convey water to the highest corner of the field, and permanent ditches are extended along one or two boundaries and occasionally within the interior of field. The land is then deeply plowed and well graded. A sketch of a useful implement for grading is shown in figure 13. It consists of an oak frame attached to three low metal wheels and two steel-shod wooden runners. The cutting blade is 5½ feet long, 20 inches wide, and curved. The blade is raised

[a] The subject of preparing land for irrigation and methods of applying water is fully discussed in U. S. Dept. Agr., Office of Experiment Stations Bul. 145.

or lowered by means of a hand wheel, and when a load has been collected by cutting off the knolls the machine is locked by the foot of the teamster and driven to the nearest low place, where it may be dumped in a heap or scattered out in a thin layer. It takes two horses to pull it in loose, granular soil, but three and occasionally four may be required in firm, hard soil. The cost is about $40. When land is covered with a heavy growth of sagebrush or when it is uneven, consisting of sand hummocks or heights and hollows, it is not best to attempt to complete the preparation of the surface the first season. The ground may be roughly prepared and seeded to grain or planted to potatoes. Later in the season it is irrigated as well as the nature of the surface will permit, and afterwards when the crop is removed it is thoroughly prepared for a permanent crop, like alfalfa. The roots of native grasses are then dead and the sagebrush roots interfere to a much less extent with scrapers, graders, and other farm implements. Besides, in the mountain States fields that are to be seeded to alfalfa should be prepared in the fall in order to sow the seed sufficiently early in the spring.

FIG. 13.—Grader.

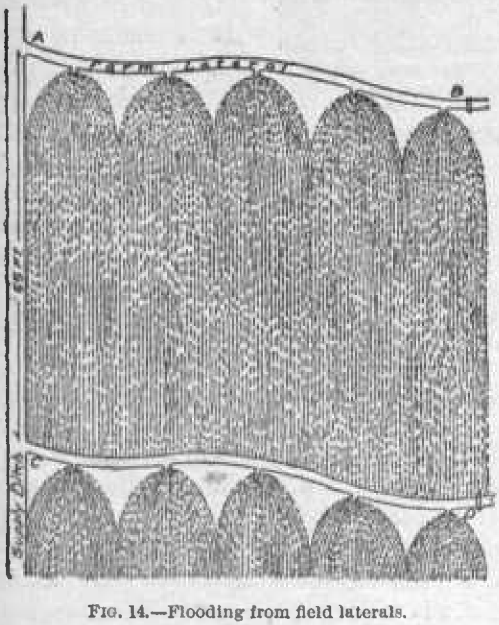

FIG. 14.—Flooding from field laterals.

Field laterals.—When a field has been leveled and graded, small ditches, called field laterals, are run through it. This work may be done either before or after seeding. On fields intended for alfalfa or meadows the laterals are made larger and with more care. They are usually located on a grade of from one-half to three-fourths of

an inch to the rod, and are spaced about 75 feet apart in grain fields, and about 90 feet apart in alfalfa fields. Sometimes the laterals extend down the steepest slope from the supply ditch. Figures 14 and 15 indicate these two methods of locating laterals. Small laterals may be made with a common walking plow, but a lister plow attached to a sulky frame is to be preferred for medium-size ditches. The larger laterals, designed to carry 200 miner's inches, may be easily made by riveting together two steel beam plows, one with a right and the other with a left hand share. The manner of applying water to crops from field laterals is referred to on pages 29-36. This method appeals to the poor settler, because it is less costly than most others. The cost of grading the surface in this way and building field ditches will vary from $2 to $5 per acre, depending on the natural condition of the land in its raw state.

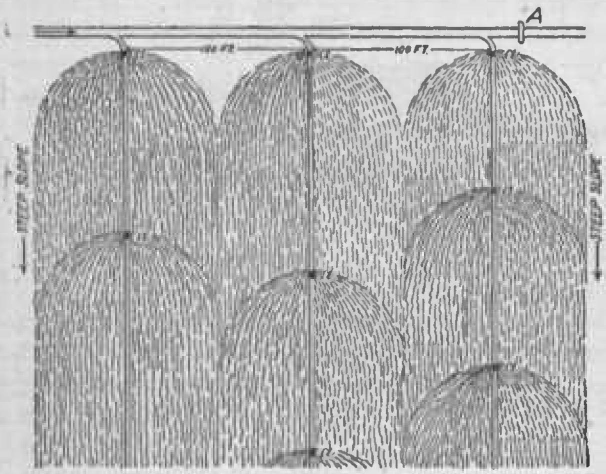

FIG. 15.—Flooding from ditches running down teepest slope.

Irrigation by flooding.—The flooding system may be used when the land to be irrigated is reasonably cheap and abundant; when the water is delivered either continuously or in small heads for given periods of time; when the members of a family can do the irrigating; when grain and forage crops are to be raised, and when a rotation of crops is desired.

PREPARING LAND FOR FURROW IRRIGATION.

Furrow irrigation.—Nearly all crops that are planted in rows and cultivated are irrigated by means of furrows. This applies to such crops as potatoes, sugar beets, corn, vegetables, and fruit. The ground is first plowed, leveled, and graded in much the same way as that just described. The field is then divided so that each part can be readily watered from a head ditch. The distance between any two consecutive head ditches depends chiefly on the soil. In porous, sandy soils furrows should not be more than 300 feet long. In soils which absorb water less freely they may be 400 to 600 feet long. These head ditches are fed from the main supply ditch of the farm, and are usu-

ally made after the field is partially leveled and graded. A useful implement for cleaning out these head ditches after being plowed is shown in figure 4, page 14.

Division of water among the furrows.—The chief trouble in furrow irrigation is to divide the water in the head ditch somewhat equally among a large number of furrows. The irrigator may wish to turn water into fifty furrows at the same time and, unless he uses some device other than a shovelful of dirt taken out of the ditch bank, the distribution will not be uniform. One of the best devices yet used for this purpose is a short pipe or spout, which may be made of wood. For small amounts of water less than 1 miner's inch, two pine laths cut in two and the four pieces nailed together in the form of a pipe answer very well. For larger streams, requiring from 1 to 6 miner's inches, half-inch boards of the required width are used in place of the half laths. Figures 16 and 17 show these two forms of wooden spouts. A pipe is inserted in the lower bank of the head ditch opposite each furrow and placed 2 or 3 inches below the surface of the water. In some localities where water is scarce and valuable, flumes and pipes of various kinds are used to convey and distribute the water to furrows. A sketch of a distributing flume built of wood is given in figure 18 and one of cement concrete in figure 19.

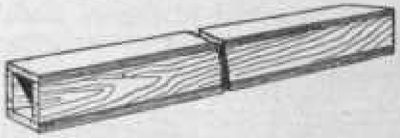

Fig. 16.—Lath pipe for ditch bank.

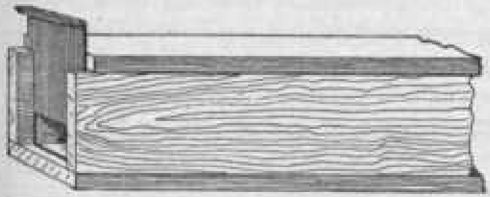

Fig. 17.—Pipe for ditch bank made from half-inch boards.

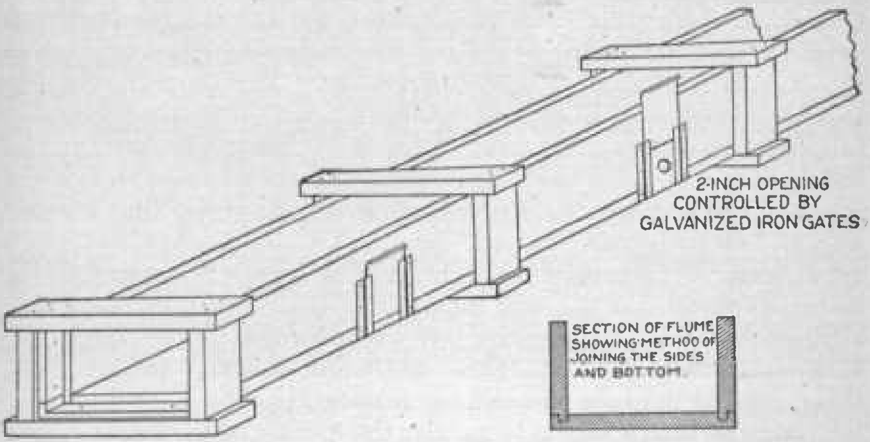

Fig. 18.—Wooden flume.

Grading between ditches.—Having laid out a field in the proper manner as regards head ditches, and having provided some effective way of getting the same amount of water in each furrow, the only important thing remaining to be done is to properly grade the tracts between the ditches. This should be well done in order to allow a small stream to flow down each furrow. The implements already referred to will properly grade the surface.

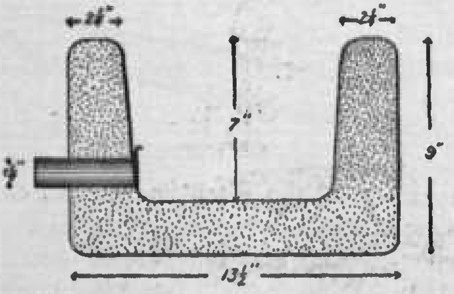

Fig. 19.—Cross section of 8-inch cement flume.

PREPARING LAND FOR CHECK IRRIGATION.

The check method of irrigation is confined mainly to alfalfa. It consists in dividing up a field in contour, or rectangular checks, each comprising, as a rule, from one-half acre to 1½ acres. Around the margin of each check a low embankment or levee is formed which retains the water until it has been absorbed by the soil. The manner of laying out and building the checks has been quite fully described in Bulletins 145 and 158 of the Office of Experiment Stations, and the reader is requested to read these descriptions to supplement the following:

Laying out the field.—The field to be checked is first to be laid out in contour lines—lines connecting points of equal elevation—the difference in level between any two being from 3 to 6 inches or more, depending on the slope. With 3-inch contours on land which slopes 8 feet to the mile, the contour lines would be about 160 feet apart. On steeper slopes this space is decreased and the elevation between adjacent contours increased. Land which slopes 50 feet or more to the mile is not suited to check irrigation. The contours may be located by the use of an engineer's level and rod, or by the homemade level already described (p. 15). When the contour lines are run the intervening spaces are subdivided into areas containing on an average about three-fourths acre. Provision is also made at this time for field ditches to convey water to each check. After temporary stakes are set to mark the corners of the checks a plow furrow is run around the margin of each so as to mark it permanently. This being done, portions of the field may be checked whenever the farmer has time. Many farmers prefer rectangular to contour checks. In laying out these, contour lines are run and the rectangular checks are fitted into the spaces in such a way as to require the moving of the least possible volume of earth. Such checks cost more, but they are more convenient for farming operations.

Building levees.—In building the levees around checks a scraper drawn by two to three horses or mules is generally used. All knolls

and hummocks within the check are first scraped down and the earth placed in the levee. If more dirt is needed, the high corner or end of each check is removed, leaving the floor fairly level, or with a slight grade away from the check box where the water is admitted. The field is then plowed, harrowed, and seeded in the usual way.

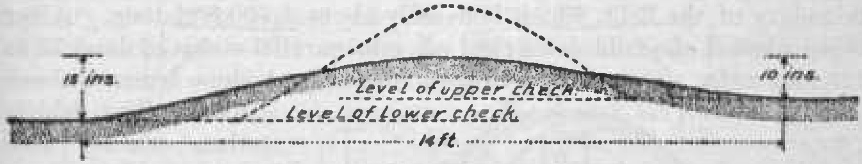

FIG. 20.—Low and broad check levee.

Levees when first built are too high and steep, but with the subsequent plowing, harrowing, and settling they should become similar to figure 20 about the time the first crop of alfalfa is ready to cut. The dotted line in figure 20 represents the general shape of the levee when first formed.

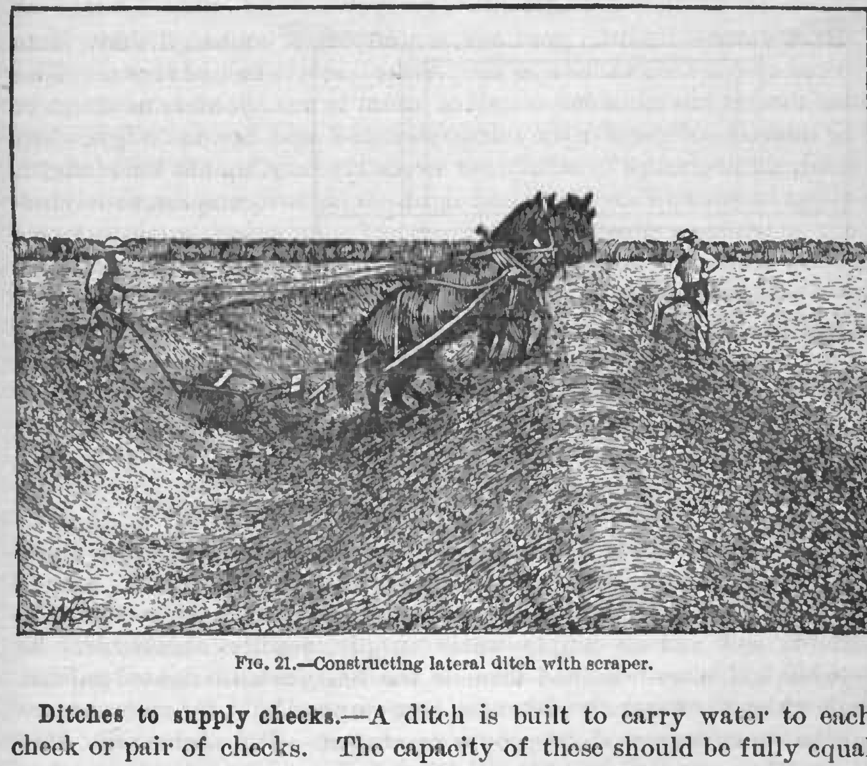

FIG. 21.—Constructing lateral ditch with scraper.

Ditches to supply checks.—A ditch is built to carry water to each check or pair of checks. The capacity of these should be fully equal to the head used, which in California is about 10 cubic feet per second. The shape of such a ditch in course of construction is shown in figure 21. Each check should be provided with a box controlled by a

gate. These boxes are made of wood or concrete. A wooden box of the common type is represented in figure 22.

PREPARING LAND FOR BORDER IRRIGATION.

In the border method of irrigation a large head ditch capable of carrying about 10 cubic feet per second is first built across the highest boundary of the field, which is usually about 1,300 feet long. After being plowed the field is marked off into parallel strips of land 75 to 125 feet wide. These extend down the steepest slope from the head ditch. The field is then crossed with teams drawing scrapers, which remove dirt from the knolls and high places and deposit it along the borders. This operation is similar to that of raking hay into windrows. The borders need not be made high, but should be straight, compact, and rounding, so as to retain the water and facilitate the passage of mowers and reapers. In preparing the land care should be used to obtain an even slope between the borders to enable the water which is admitted through a box in the head ditch to flow in a thin sheet from top to bottom of each strip.

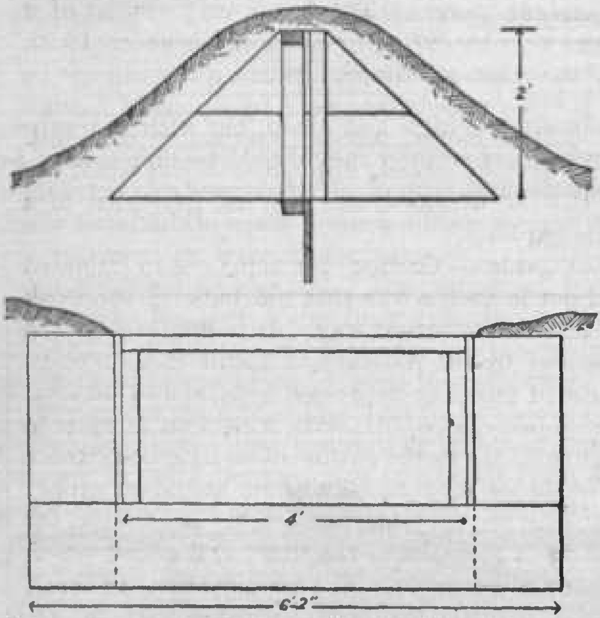

FIG. 22.—Check box, showing section across embankment at top and lengthwise of bank at bottom.

PREPARING LAND FOR GARDEN IRRIGATION.

For obvious reasons the farm garden which is intended for growing small fruits and vegetables for home use should be located as near to the farm buildings as possible. The next factors in importance are suitable soil and an ample water supply, readily obtainable. As regards soil, a well-drained loam is the best for an irrigated garden. Soils which are naturally either too heavy or too light for such purpose can be much improved by proper treatment. For adobe soils, Professor Wickson, director of the California Experiment Station, recommends the use of air-slaked lime, deep and thorough tillage, and the plowing in of as much coarse material as possible. "Farm-yard

manure," he states, "straw, sand, old plaster, coal ashes, sawdust, almost anything coarse or gritty which will break up the close adherence of the fine clay particles, release the surplus water, and let in the air, will produce a marked effect in reducing the hateful baking and cracking, root-tearing, and moisture-losing behavior of the adobe."[a] For improving a light sandy soil the same author recommends the use of plenty of well composted and decayed manure.

The water supply.—The water supply for the garden should be taken from the main supply ditch, as shown in figure 23, or it should be derived from an independent system. The latter may consist of a small pipe laid from some near-by spring or creek and connected with a tank or reservoir near the ranch buildings. When water can not be conveyed by gravity it is often raised from wells by means of a small pump operated by an electric motor, gasoline engine, or windmill. These small independent systems should furnish sufficient water for domestic purposes, for the use of stock, and for the irrigation of a small fruit and vegetable garden.

A plan for an irrigated garden.—Gardens for home use in irrigated districts should be laid out in such a way that the bulk of the work can be done by teams and in the easiest way. It is doubtful if the laborious methods practiced by the Asiatic and Latin races in cultivating by hand, in the use of raised or depressed beds, and in seasonal rotation of crops will ever become popular with American farmers in irrigated districts. Figure 23 shows the outline of an irrigated garden which is intended to provide the farm home with an abundant supply of fresh fruits and vegetables for the table, and freshly cut alfalfa, for poultry, a few pigs, and for a cow part of the time, at the least possible amount of manual labor and trouble. The tract contains 1¾ acres, being 440 feet long and 170 feet wide, between woven-wire fences. The main supply ditch of the farm and a lane or public road extend along one side and the farm buildings abut it on another. A head ditch or flume taps the supply ditch and extends across the upper end. The garden is divided into three parts, the small fruits and other perennials being planted at the far side, the vegetables next, and a strip of alfalfa of the same size as that occupied by the vegetables next to the fence. This provides, when desired, a convenient rotation. At the end of two years the strip of alfalfa or clover may be plowed under in the fall and vegetables planted the following spring. The plat first planted to vegetables may then be plowed and prepared for irrigation in the manner described under the border method of irrigation and seeded to alfalfa or clover. There is also a strip 15 feet wide at the upper end of the garden seeded to alfalfa or clover. On this the teams turn in cultivating between the rows. There is a like strip

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[a] California Vegetables in Garden and Field. By E. J. Wickson, p. 49.

in forage crops at the foot of the garden which serves the same purpose and also utilizes the waste water which is apt to escape from the furrows. In order to serve this twofold purpose it is made 25 feet wide. In case a two-years' rotation of crops between the vegetables and alfalfa or clover is not considered necessary or desirable, the garden may be made longer and narrower and the lower portion seeded to alfalfa to be retained permanently.

IRRIGATING DIFFERENT CROPS.

ALFALFA.

Preparation of soil and sowing.—Alfalfa is most commonly irrigated by being flooded from field laterals. In certain localities it is irrigated by checks, in others by borders, and in a few localities by furrows. Sowing alfalfa seed with a nurse crop like oats or wheat was more common fifteen years ago than it is at the present. The prevailing usage now, except in Utah and parts of Colorado, is to sow only alfalfa seed. The soil should be thoroughly prepared. This holds true for each of the methods of irrigation previously named. Alfalfa is a tender plant for the first few months of its growth and requires favorable conditions. The soil when the seed is sown should contain sufficient moisture to nourish the plant until it is several inches high and covers the ground fairly well. In the colder and higher States of the West the necessary moisture may be secured by preparing the fields the previous fall and permitting the deeply plowed land to absorb a large part of the rainfall and snowfall. Then in the spring, as early as the ground is fit to work, it is again cultivated, after which the seed is sown. In the warmer States the fields are likewise prepared in the fall, but instead of depending on rain from passing clouds the soil is well irrigated, and this added moisture sinks deep into the soil, which is subsequently cultivated and seeded.

Early treatment of crop.—If skill is used in providing an ample supply of moisture before the seed is sown there will be no need of early irrigation. Mistakes are frequently made by sowing the seed on too dry soil and then applying water at frequent intervals when the plant is young. This practice causes the roots to branch out near the surface and to depend for food and moisture on the top layers of soil, which are subjected to extremes of drought and moisture. When the soil is fairly moist at time of planting and the surface is thoroughly cultivated so as to retain the moisture there will be no need of applying more until the crop shades the ground. Meanwhile the alfalfa may suffer slightly, the leaves, and even the stems, may become brown, but in its effort to survive by getting moisture it will extend its taproot far down into the subsoil. Forcing the plant to hunt for moisture from beneath and keeping the surface layer dry

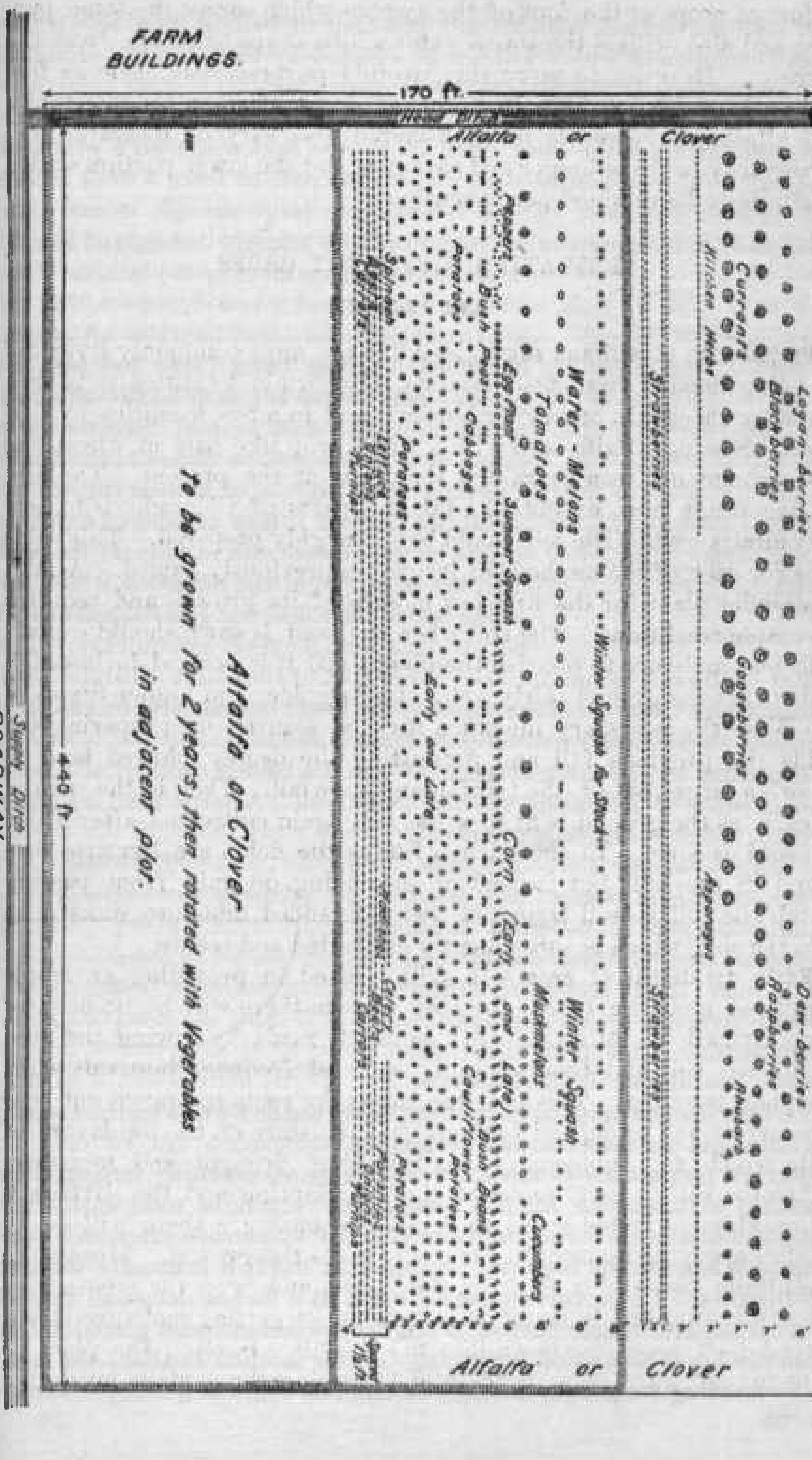

Fig. 26.—Plan of irrigated garden.

and well pulverized, without any crusting or baking, produces a fine root development which will not be affected by the alternate droughts and saturations of the surface layers.

Irrigation by flooding.—In irrigating alfalfa by flooding, field laterals are run out from the head ditch 75 to 100 feet apart on a grade of one-half to three-fourths of an inch to the rod, or from 3 to 4½ inches fall in each 100 feet. These laterals are large enough to carry the head used, which may vary from 50 to 100 miner's inches, and should be made at the time the crop is planted. One irrigator can attend to two streams which are kept running in adjacent laterals. At given distances, varying from 75 to 150 feet, he places some temporary dam in the channel, which stops the flow in that direction and causes it to flow over low places in the bank. The dam used may be of canvas (fig. 24) or metal (fig. 25), or it may consist of a pile of coarse manure faced with earth. If the seed drill has been run in the direction which the water takes after leaving the laterals it will help to distribute it evenly and quickly. The water is allowed to run until the upper foot of the soil is saturated, any excess which runs off being caught by the lower lateral. By this method one man in ten hours will irrigate from 2 to 5 acres.

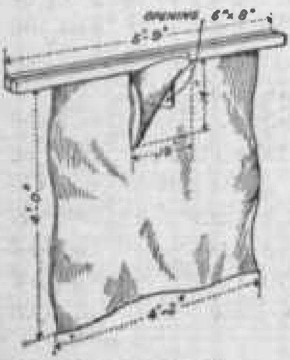

FIG. 24.—Canvas dam.

Irrigation by the check system.—When the land is checked, the labor and expense of irrigating are much reduced. A large head of water is used, which is turned into a check by simply raising a wooden gate. When sufficient water has been admitted, a gate to the next check is opened and the first one closed. Two men in twelve-hour shifts should irrigate, on an average, 15 acres per day. Assuming that their wages, board, and implements cost the owner $5 per day, the cost of applying water by this method would be 33⅓ cents per acre for each irrigation.

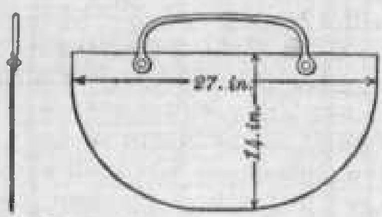

FIG. 25.—Metal dam, or tappoon.

Furrow irrigation.—Some soils can not be successfully irrigated by flooding or in checks, for the reason that very light soils wash when flooded and a crust forms on the surface of other soils after each wetting. When alfalfa is grown on soils that bake, it is usually watered by furrows. These furrows are from 3 to 6 inches deep and from 2 to 4 feet apart. Each furrow is fed by a wooden spout placed in the head ditch. The cost of irrigating by this method is about the same as by flooding from field laterals, or from 50 cents to $1.25 per acre.

Irrigation after first crop.—In many sections the rainfall during the spring months supplies sufficient moisture for the first crop. Each subsequent crop is irrigated once, as a rule. Opinions differ as to the proper time to irrigate. The custom in the Yellowstone Valley, Montana, is to irrigate the land before the crop is cut. The grower decides upon a date a week or ten days in advance when his alfalfa will be ready to cut. He likewise estimates the number of days it will require the soil to dry out sufficiently after an irrigation to enable the mower and wagon to pass over the surface without any injury to the field or the next crop. The field is accordingly first watered and then the crop is cut and stacked. The custom in Utah is to harvest the crop first and then apply water to the stubble. What would be good practice in one locality might be bad practice in another. The size of the farm has much to do with the case. On small farms the crop may be removed in the forenoon and the water applied in the afternoon. On large farms several days may intervene, and by that time the stubble is withered to such an extent that it may take a week to restore the lost vigor of the crop. The main thing to keep in mind is the necessity of keeping the plant growing vigorously all the time. Any practice which checks the growth should be modified.

GRAIN.

Method of irrigation.—Grain fields are usually irrigated by flooding from field laterals. Furrow irrigation is practiced only where the soil bakes after being flooded. Check and border methods of grain irrigation are confined to limited areas in Arizona and California. The most of the irrigated grain is raised in the mountain States in rotation with a leguminous crop, like alfalfa or clover. In some localities potatoes or beets form a part of the rotation. In rotating with cereals and legumes, or with cereals, legumes, and roots, the flooding method is readily adapted to each kind of crop. This accounts in part, at least, for its general adoption in most irrigated districts.

Preparation of the land.—As a rule, the land should be plowed in the fall and seeded as early as possible the following spring. The time of plowing is determined largely by the rainfall and the fitness of the soil. The time of seeding is likewise determined by these same conditions, and also by the occurrence of frosts. The methods employed in grading and leveling are similar to those previously described. When the grain is from 4 to 6 inches high, the field laterals are run out. These extend on grade lines from the head ditch and are spaced 60 to 70 feet apart. If the surface has been well prepared, a grade of one-half inch to the rod will be ample for the laterals. On less even ground the grade should be increased to three-fourths of an inch or more per rod. Each lateral should be made large enough to carry about 50 miner's inches. An irrigation stream of 80 to 120 inches

may be divided equally between two laterals and one of 130 to 170 inches between three laterals. In the plan shown in figure 14, page 21, the stream is divided between two laterals, A–B and C–D. The flow in A–B is checked at B and in C–D at D. The checks used at B and D may be canvas dams, metal tappoons, or manure heaps faced with earth on the upstream side. When the space between A–B and C–D is watered, the check dams at B and D are removed and placed in a similar manner 75 feet lower down. This operation is continued until the entire field is irrigated.

When to irrigate.—No fixed rule can be laid down for the proper time to irrigate grain. The soil should contain sufficient moisture at seed time to nourish the crop until it shades the ground. A quantity of water varying from 4 to 9 inches in depth over the surface may then be applied at one irrigation. A second irrigation is usually applied when the grain is beginning to head out. This seems to be the critical period in the irrigation of grain. The plants are using at this time the maximum amount of moisture, and as soon as there is a deficiency they begin to suffer. When the growth is checked at this stage, the lost vigor can not be wholly restored by subsequent watering, and the yield is lessened. The amount of water required by cereals during the first six weeks of their growth is small, if one excepts the heavy loss by evaporation from the surface of newly cultivated and seeded fields. The amount of water required during the last three weeks of growth is likewise small. The number of irrigations during the intermediate period of forty to sixty days varies from one to four, depending on local conditions. After the last irrigation has been applied the banks of the field laterals are leveled with a small walking plow, drawn by one horse. The field is then ready to harvest.

POTATOES.

System of irrigation employed.—Potatoes and other root crops are irrigated by furrows made midway between the rows. These furrows should not be over 600 feet long, and in light sandy soils with little fall this distance should be reduced. The length of the furrows may be readily shortened by putting in more head ditches. Short furrows insure a more even distribution of water, and frequently prevent injury to the crop by the water-logging of a part of the soil.

The best soil for potatoes and the best rotation.—A well-drained, sandy, or gravelly loam, rich in decayed vegetable matter, is the best for this crop. If the soil is wanting in organic matter it should be supplied by the right kind of a crop rotation. In Colorado a common practice in raising potatoes is to grow alfalfa for two years, then plant to potatoes for two years, and at the beginning of the fifth year seed to wheat and alfalfa. In turning down alfalfa in the spring before planting potatoes, the field should first be irrigated and afterwards plowed

from 6 to 8 inches deep when the soil is dry enough to crumble into small particles as it falls from the moldboard.

Selection of seed and early cultivation.—Potatoes grown on irrigated land are not the best for seed. They seem to be more subject to disease. Smooth, round tubers, free from disease, and grown on non-irrigated land, should be planted 38 inches apart and 4 inches deep. The soil is well cultivated between the rows and the whole surface harrowed before the potatoes come up. During the first stages of growth cultivation is the essential thing. If the ground has been irrigated before planting, one heavy irrigation at the time the tubers are beginning to form may be sufficient. In other cases from two to four waterings may be required. The important thing to remember is to keep the top layer of soil well pulverized by frequent cultivations and to supply enough water to produce moist soil beneath this surface mulch. The amount of moisture in the soil around the roots should vary as little as possible, except when the tubers are beginning to form, when it should be increased, since this is the critical stage in the life of the plant and more water is required.

Irrigation practice.—The most common mistake in the irrigation of potatoes is to turn in a large head in each furrow, permit it to flow rapidly to the bottom of the rows, and then shut it off. This way of applying the water wets only the surface layer, and if it is not followed up immediately by cultivation a couple of days of sunshine will rob the soil of most of the water which has been applied and seal over the surface with a hard crust. In this condition the crops soon begin to suffer, and the unskilled farmer fancies that the only remedy lies in applying more water. A better plan is to turn only a small amount of water into a deep furrow and permit it to run without stopping for hours or even for half a day. In this way the top layer is not saturated, the soil around the roots and beneath them receives a larger supply, and the surface may be cultivated shortly after each irrigation, so as to check evaporation and retain the moisture in the soil for the benefit of the crop.

FRUIT TREES.[a]

Planting.—According to Director Wickson, of the California Experiment Station, apple trees should be planted on an average about 28 feet apart; cherry, plum, prune, apricot, peach, pear, and olive trees about 24 feet apart, and citrus trees 20 feet apart. On ordinary slopes, from 10 to 100 feet to the mile, the trees may be planted in rows down the steepest slope. Where the ground is so steep that water flowing in furrows will scour the bottom, the tree rows should extend diagonally across the slope so as to lessen the grade. On rolling

[a] The methods adopted in applying water to orchards in California are described in U. S. Dept. Agr., Office of Experiment Stations Buls. 108 and 145.

ground the trees should be planted on grade lines so as to conform to the natural surface and render easy the task of applying water.

Irrigating.—The common method of irrigating fruit trees in western America is by furrows from 500 to 600 feet along. There is, however, a wide difference in practice in the distribution of water from the supply ditch to the head of each furrow. This is done in the mountain States by making openings in the ditch bank with a shovel opposite each furrow. While this is the cheapest method it is not the best, because one can not divide the head evenly among the furrows, and as a rule the greater number receive far too much water. When 5 or 6 miner's inches are turned into a furrow on a fairly steep slope the part which is not absorbed soon flows down to the end where it is wasted. The passage of this head for a short time saturates only the top soil, which will afterwards crust over to the injury of the trees and the loss of water by evaporation. Some device resembling the wooden spout previously described (p. 23) should be used to regulate the flow, and excepting in sandy soil permit only a small stream to flow in the bottom of each furrow for a much longer period. In localities where water is valuable the earthen head ditch is seldom used. Water is distributed to the furrows through small openings in wooden flumes (fig. 18) or else through similar openings in cement flumes (fig. 19). At the present time cement pipes and sewer pipes, as well as metal pipes, are quite extensively used in the citrus orchards of California for this purpose.

Cultivation and water requirements.—Those who intend to plant orchards will learn from subsequent experience that the following suggestions are in accord with the best practice at the present: When the tract is planted with the right kind of stock the next most important thing is frequent and thorough cultivation. The surface should be cultivated after each rain and after each irrigation, and occasionally in the intervals. The proper depth to cultivate will depend on a variety of conditions, but it is well to bear in mind that if anything like complete protection from soil evaporation is desired the cultivator teeth should be lowered to 8 inches beneath the surface. If thorough cultivation is practiced frequent irrigations will not be necessary, because the moisture will be retained in the soil beneath the dust mulch. Irrigation at intervals of thirty to forty-five days during the irrigation season will provide ample moisture for ordinary loamy soils. The length of the irrigation season varies from one to twelve months, according to the rainfall, temperature, crop, etc. Young trees are watered by a furrow on each side of the row and, as the trees grow older and larger, the number of furrows is increased until all the space between the rows is watered. The idea to be kept in mind is to train the roots outward and downward so as to enlarge their feeding zone. The best

guide to successful practice is to make frequent excavations to find out not only the location of the roots, but also how far and in which directions the water from the furrows has percolated. The perfect way of watering fruit trees would be to keep the surface dry, not disturb the dust mulch, and apply the water beneath. This is not practicable, but the skillful irrigator can approach this ideal practice by making deep furrows, using a small stream in each, and letting it run for two or three days at a time.

SMALL FRUITS AND VEGETABLES.

The small fruits and vegetables included in the farmer's garden, of which an outline is shown in figure 23, page 28, are arranged so that the crops which require similar treatment in the way of spacing, cultivating, and irrigating are placed in the same row or in bordering rows.

Loganberries and dewberries occupy the first row. These are planted 3 to 4 inches deep and 4 feet apart in the row, with a space of 7 feet between the rows. They are irrigated by a small furrow on each side of the row, and the soil is well cultivated after each irrigation. The vines are cut back after the first year's growth, and in the following spring a low, flat ridge is formed to keep the irrigation water from wetting the vines and fruit.

Blackberries and raspberries are set out in a deep trench, 4 and 3 feet apart, respectively. For the first season the water in irrigating will follow this trench. In subsequent seasons it should be applied in furrows between the rows.

The cuttings of currants and gooseberries are taken from the nursery or from the parent bush and set out about 6 inches deep and 3 feet apart. The water is applied in furrows which are run near the plants the first season. In subsequent seasons all the space between the rows is moistened by running water in two furrows and cultivating afterwards.

Asparagus roots when taken from the seed bed are planted about 2 feet apart in a trench enriched with well-rotted manure. They are covered with fine loam 3 inches deep, and as the plants grow more fine loam is placed around the roots until the trench is filled. The first waterings may be applied in the trench and afterwards from one or two furrows in the open space.

Squash, melons, cucumbers, tomatoes, corn, and cabbage are planted in the usual way on soil which should be adapted in texture and richness to each variety. The standard method of irrigating these crops is by furrows run between the rows. In making the furrows and applying the water the main purpose kept in view is to moisten the soil uniformly to the required depth without wetting the vegetables and with the least possible wetting of the surface.

For convenience in irrigating a garden the head ditch should be a wooden flume with holes in the side to admit water to each furrow. Those who can not afford the expense of a flume should insert small wooden spouts (fig. 17) in the lower bank of the head ditch, opposite each space.

Plants like carrots, beets, turnips, etc., which are planted in rows 18 inches apart and cultivated by hand, may be all watered at one time in the following manner: A stream of about 6 miner's inches may be taken from the head ditch and conducted along one border. This stream may be divided into three small heads, one-third being used to irrigate the upper part of the vegetables named, the other applied to the middle part, and the balance to the lower part. By this arrangement about 2 miner's inches are divided up among five rows, which are shortened to 133 feet. Any waste water which collects at the foot of each division may be led into the main furrows at the edge of the field.

HOW TO LESSEN THE WASTE OF WATER.

Loss by absorption and seepage.—Recent investigations made by the Office of Experiment Stations have shown that the quantity of water which plants use forms but a small part of that which is diverted from streams for irrigation purposes. Large volumes are lost by absorption and seepage in the earthen channels of canal systems. Similar losses occur in the ditches which supply farms, and a large part of the remainder is wasted in irrigating crops. The farmer is chiefly concerned in lessening the waste of water in his supply ditch and on his farm. In localities where water is scarce, the supply ditch should be made water-tight. This may be done by lining the channel with cement concrete, cement plaster, asphalt, heavy crude oil, or clay puddle. Flumes or pipes may also be used as a substitute for an earthen ditch.

Loss from faulty preparation of surface.—One of the most common sources of loss of water is poor preparation of the surface. When the soil is irrigated by flooding from field laterals an uneven surface causes needless waste of water, extra labor in spreading it over the surface, and smaller yields. The water flows into the low places, which receive too much and may become water-logged, while the high places are left without water and the crop thereon is dwarfed. The surface between field laterals should be so evenly graded that water will flow in a thin sheet over the entire surface, the excess being caught up by the lower lateral.

Loss from neglect.—Another common cause of waste is the lack of attendance. Water is often turned on a portion of a field and permitted to run without attention for hours and even days. On some farms the irrigators look after the water for ten hours and turn it loose for the

balance of the day. Under this practice the low places receive too much, the high places little or none, and a large part flows off the field to the injury of the roads and adjoining farms.

Inefficient irrigation.—Too shallow and too frequent irrigation is another source of waste. Wetting the surface and neglecting to cultivate it afterwards may result in the loss by evaporation of three-fourths of the water which is applied in this way. For most plants, and for all deep-rooted plants in particular, the ground should be so prepared that water would readily percolate to a considerable depth beneath the surface and enough water should be applied to moisten the subsoil.

Utility of cultivation.—Again, in farming by irrigation thorough and frequent cultivation is of first importance. It not only prevents the escape of large quantities of soil moisture into the air in the form of vapor, but it greatly improves the condition of the soil.

RIGHT QUANTITY OF WATER TO APPLY.

The amount of water to apply in one irrigation, the length of the interval between irrigations, and the total quantity used in any one season all depend on a large number of soil, crop, and climatic conditions. The limited space will not permit these to be fully considered. Accordingly, only those features which seem to be of greatest interest to the irrigator are touched upon.

PROPER PERCENTAGE OF SOIL MOISTURE.

Why irrigation is practiced.—The main purpose of irrigation is to furnish the requisite amount of moisture to cropped soil. Too little, as well as too much, moisture in soils injures plants, and it is not easy to find out how much is best for each kind of soil and for each kind of crop. About three-fifths of the volume of clay soils and two-fifths of sandy soils is open space, while the loams range between. The greater part of the water found in the open space furnishes moisture to the roots of plants; the remainder clings to the soil particles and requires a considerable amount of heat to drive it off in the form of vapor. The irrigator need only concern himself with the former, which is known as the free water in the soil, since it nourishes his crops. One of the first questions which confronts the irrigator is to know how much of this free water soils should contain in order to produce a vigorous growth. The answer in general terms is, about 1 pound of free water to 10 pounds of soil as it is taken from a field.

Percentage of soil moisture.—Farmers in irrigated districts can find out for themselves the proper percentage of soil moisture. All that is necessary is a soil auger and a balance scale to weigh the samples. The price of the scale will vary from $3 to $5 and that of a suitable auger from $1 to $2.50. The samples should be taken from the soil

around the roots of the cultivated plants. If these roots extend from 6 inches to 4 feet below the surface, then the sample should be an average of this 42-inch layer, or else separate samples should be taken at various depths. The sample of earth should be immediately placed in a glass fruit jar and the cover screwed down tight on a rubber band. It is afterwards weighed by taking an even number of ounces. Assume that 100 ounces is the weight before drying, and that after the sample is spread out thin over a tin pan and exposed to the sun for the greater part of a day it weighs only 90 ounces, this would indicate that there is 1 ounce of free water for every 10 ounces of moist soil. It will be found that a balance which weighs in grains will be more convenient. Thus if weights equal to 100 grams are placed in one pan and balanced with a part of the sample of soil in the other pan, and if the same after being thoroughly sun dried weighs 96 grains, it would indicate that there was only 4 per cent of free moisture in the soil, and that the field required to be irrigated. If the sun-dried sample weighed about 90 grams it would show that there was sufficient moisture for rapid growth, and if it weighed only 86 grams it would indicate an excess of moisture.

Quantity of moisture required to give best results.—The rule given above may serve as a guide to the beginner in irrigation during the first season. After that he should ascertain for himself the percentage of free moisture which will give the best results. This may be done by taking samples of soil from fields on which crops are doing well. It may happen that in sandy land the amount of free moisture found in the soil, around the roots of potato vines, for instance, is only 6 per cent. If the crop shows no signs of suffering for lack of moisture it may be taken for granted that this percentage is sufficient. On the other hand, if in weighing samples of soil taken from the upper 4 feet of an alfalfa field in good condition and consisting of clay loam, more than 10 per cent of free moisture is found, it may be inferred that the extra amount is required.

Moisture not the only essential.—In attempting to find out how much free moisture cropped soils should contain, it is well to bear in mind the fact that while moisture is the principal element in growing crops on arid lands it is not the only essential. Temperature, winds, sunshine, fogs, disease, and a lack of air in the soil very frequently affect crops. When, therefore, a crop is suffering an effort should be made to discover the cause and not jump to the conclusion that more water is needed.

QUANTITY TO APPLY IN ONE IRRIGATION.

What becomes of the water.—The application of 4 inches of water in depth over the surface of a field on which plants are growing fairly well is sufficient to moisten the soil to a depth of 4 feet, providing it

is evenly distributed without loss. In practice a larger volume is required if it is desired to moisten the soil to this depth. This difference between theory and practice is readily explained. In irrigating in the usual way the top layer of soil receives far too much water. A part of this seeps into the second and third feet, a part passes off into the air in the form of vapor, and the balance remains in the top layer or is utilized by the plants. Now, in this process of distribution from the surface downward there is a large amount wasted. The greatest loss of water is from the surface of moist soil into the air. Thus experiments have shown that if the surface is kept moist for four days after the water is first turned on, from 1 to 3 inches in depth over the surface will be lost by evaporation. If the soil is saturated the loss will approach the higher figure, but if the soil is only moist it will range nearer the lower figure. There is a further loss of water as it seeps downward. Some subsoils are sandy or gravelly and the water, instead of being held in the upper 4 feet, may go much deeper and soon pass beyond the deepest roots and be lost. Other fields may have a stiff clay subsoil which will not allow the water to pass through it. The effect of this is to hold the water near the surface until the greater part is evaporated. Considerable quantities of water may be allowed to run off to other fields when they are being irrigated. Hence it follows that for light irrigations, where the soil is moistened to a depth of 18 inches, from 2 to 3 inches of water over the surface would be plenty, but so great is the loss from the causes named that 4 to 6 inches are required. Similarly for heavy irrigations and for deep-rooted plants like alfalfa, 6 inches of water over the surface would convert fairly dry soil to moist soil to a depth of 4 feet, providing there was no loss, but on account of the various ways in which water may be wasted the amount required frequently exceeds 9 inches in depth over the surface.

Cultivation essential.—In localities where water is cheap and plentiful it may matter little, as regards the annual cost of the water, whether a farmer uses 6 inches at each irrigation or 12 inches. The effect of the proper use of water, however, will soon be apparent in the yield of crops and the fertility of the soil. It should be understood from the start that irrigation water can not take the place of cultivation. The labor and skill of the husbandman are needed even more in an arid than in a humid climate. Repeated trials have shown that excellent crops of all kinds can be grown with a medium amount of water, provided the soil is well cultivated and the water rightly applied.

CONCLUSIONS.

Experience throughout the arid region is demonstrating that the greatest danger to irrigated lands is lack of drainage. Water applied to crops raises the ground water, which brings with it the salts

dissolved from the soil; capillarity brings this water to the surface, where it evaporates, leaving the salts to accumulate until all vegetation is destroyed. The only insurance against this is proper drainage. The drainage conditions are therefore equally important with the water supply and should be looked into with as much care. When there is not good natural drainage it must be supplied artificially. This, usually, is as expensive as securing the water supply.

While good drainage is the only guarantee against these evils anything which will check the rise of ground water or lessen evaporation will decrease the danger. The two most effective means of accomplishing these ends are economy in the use of water and thorough cultivation, and cultivation makes possible the greatest economy in the use of water. Wherever possible water should be applied in such a way that the surface soil will not be wet, and cultivation should follow as soon as possible, and be repeated often. This will check evaporation and keep the water in the soil for the use of plants, making it unnecessary to apply more so soon as it would otherwise be needed, and in this way reduce the volume which might go to damaging the land.

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